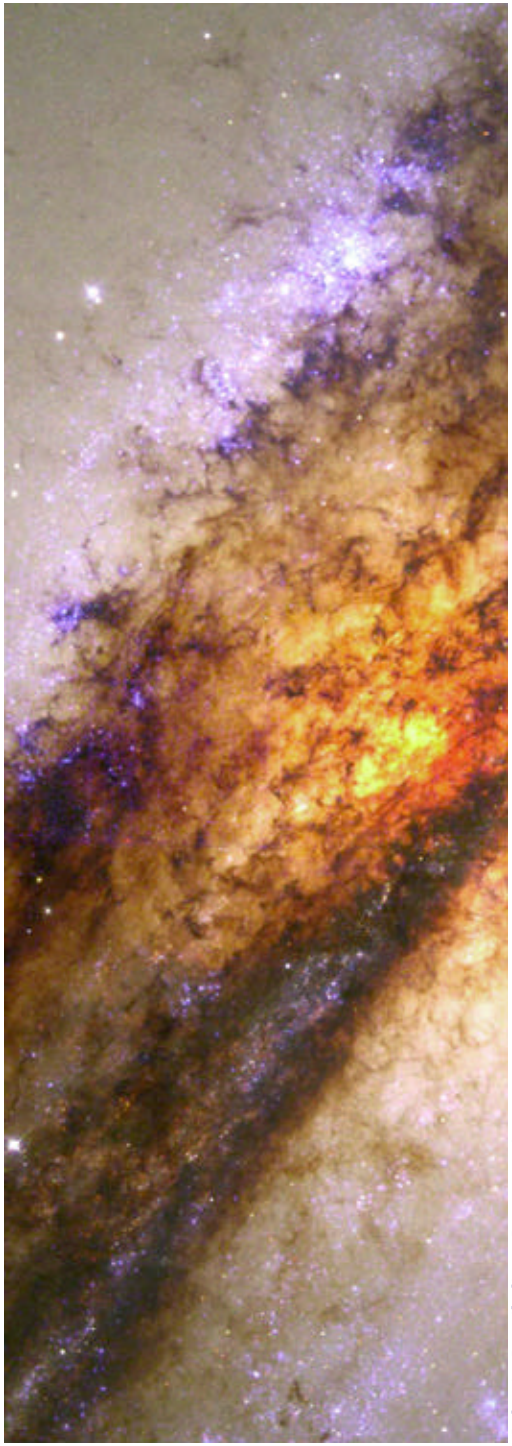


Galactic Cannibalism, Centaurus A

Next Generation Space Telescope (NGST)

Presented by

Bernard D. Seery
Project Manager

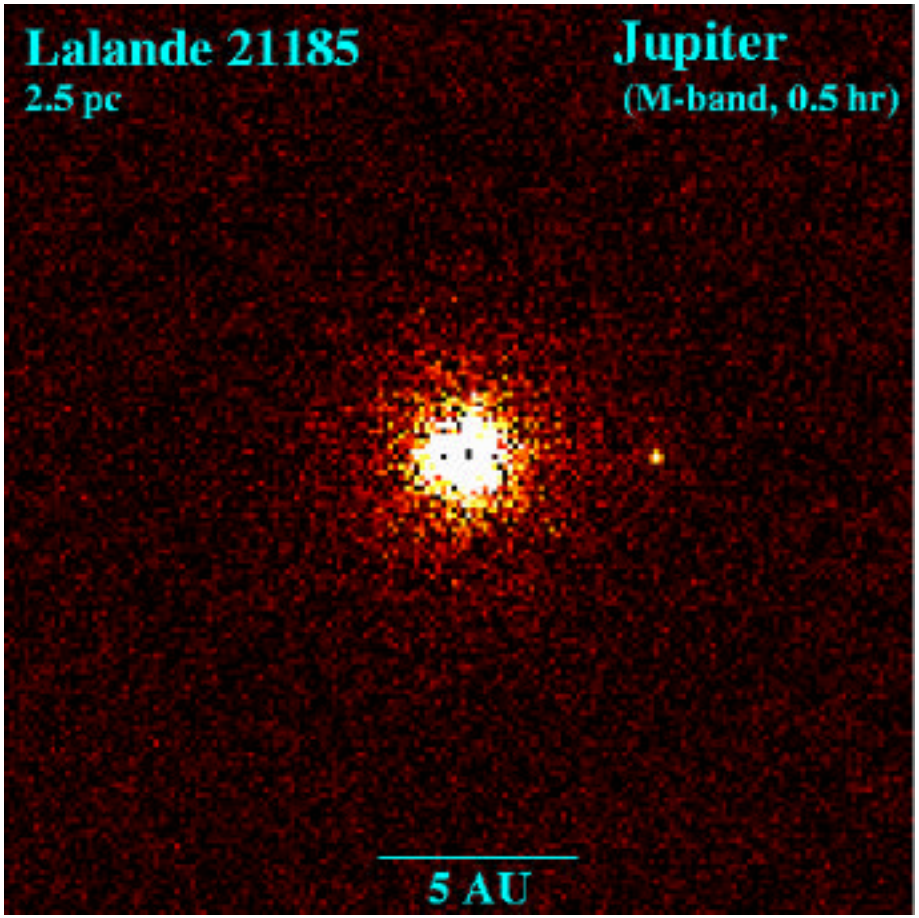
Next Generation Space Telescope

NGST

A NASA Origins Mission

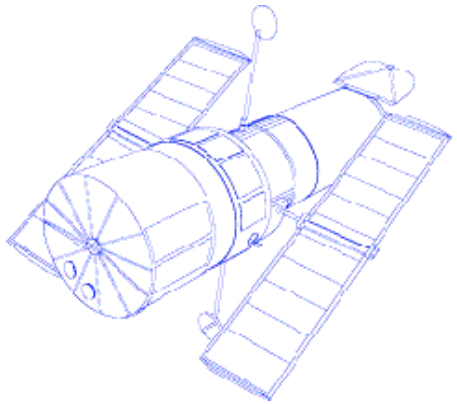
NGST and Origins

- The Origins and Evolution of Galaxies
  – *Seeing the "Dark Ages"*
- The Structure and Chemistry of the Universe
- The Physics of Star and Planet Formation
  – *Making a home for life*

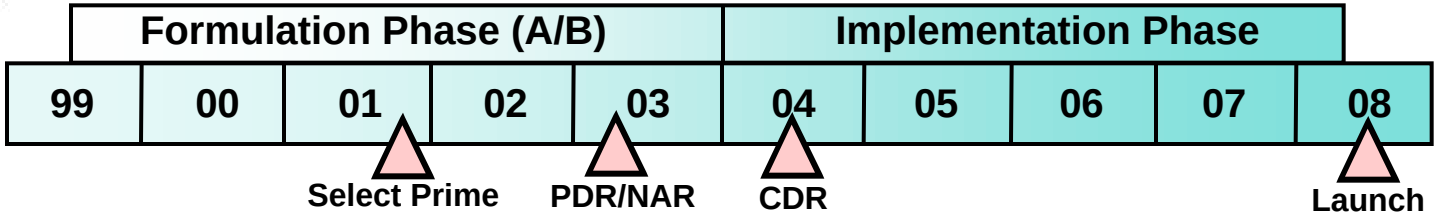


NGST at a Glance

- 8m primary mirror
- 0.6-10+ µm wavelength range
- 5 year mission life (10-year goal)
- Passively cooled to <50K
- L2 orbit



- **Logical successor to HST**
- **Key element of the Origins Program**

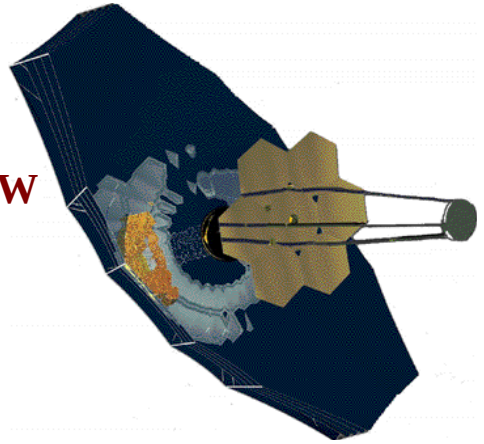


Next Generation Space Telescope
NGST
A NASA Origins Mission

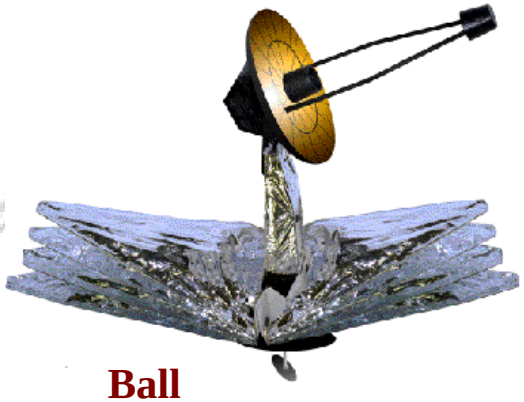
Architecture Studies

- Just completed 2 Pre-Phase A industry studies (TRW and Ball) and 1 IR&D study (Lockheed Martin)
  - 4 viable 8-meter observatory concepts capable of launch on an ELV

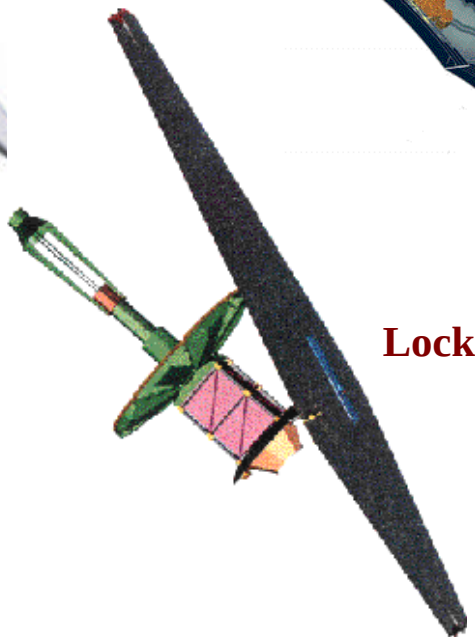
Yardstick



TRW



Ball



Lockheed Martin

Next Generation Space Telescope

NGST

A NASA Origins Mission

Outline

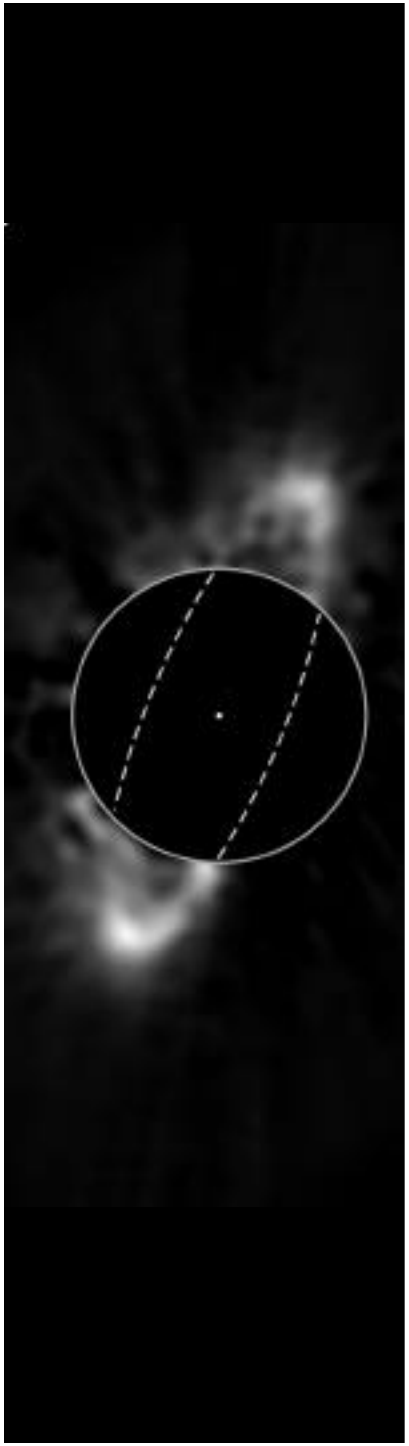
- Science
- Integrated Science Instrument Module
- Technology
- Observatory Verification
- Operations
- Outreach
- Programmatics

The Origins and Evolution of Galaxies – *Seeing the "Dark Ages"*

- When and how do the first stars and galaxies form?
  - HST and Keck have detected very luminous star forming regions/galaxies that appeared 1 billion years after the Big Bang (to Z ~ 5.6)
  - New stars appear to be forming at roughly a constant rate until very recently ($1 < z < 5$)
  - SCUBA may have detected a significant component of dust-hidden star formation at cosmological distances
- To see the growth of galaxies such as our Milky Way, we need NGST (0.6-10μm)
  - **Sensitivity** to see the first epoch of star formation (z ~ 10-20, 0.1 nJy sensitivity in 1 week)
  - **Angular resolution and wide field** to survey 100,000 protogalaxies and their environments (to z ~ 5)
  - **MIR imaging and spectroscopy** to pinpoint the nature of the hidden stars and Active Galactic Nucleii

The Structure and Chemistry of the Universe

- How did the Universe form? What is it made of?
  - Supernovae support an accelerating universe ($\Lambda \sim 0.8$)
  - Cluster X-rays & strong lensing supports a low density universe ($\Omega \sim 0.2$)
  - CMB missions (MAP, Plank) will measure small scale temperature variations 300,000 years after the Big Bang ($z \sim 1100$) to constrain cosmological parameters (Ω_m, Λ , H_0, S-Z effect)
- NGST provides direct astronomical evidence of the growth of structure and cosmological dimming (at Z ~ 1-5)
  - HST-like resolution, wide-field of view enable statistical masses of galaxies, clusters and larger structrues on scales from galaxies to galaxy superclusters (from 0.1-10 Mpc, weak lensing)
  - Type Ia and Type II supernovae (to Z>5) provide independent complementary constraints on the expansion and chemical evolution of the Universe
  - *Connects directly with study of early galaxies: distances, masses, luminosities, etc.*



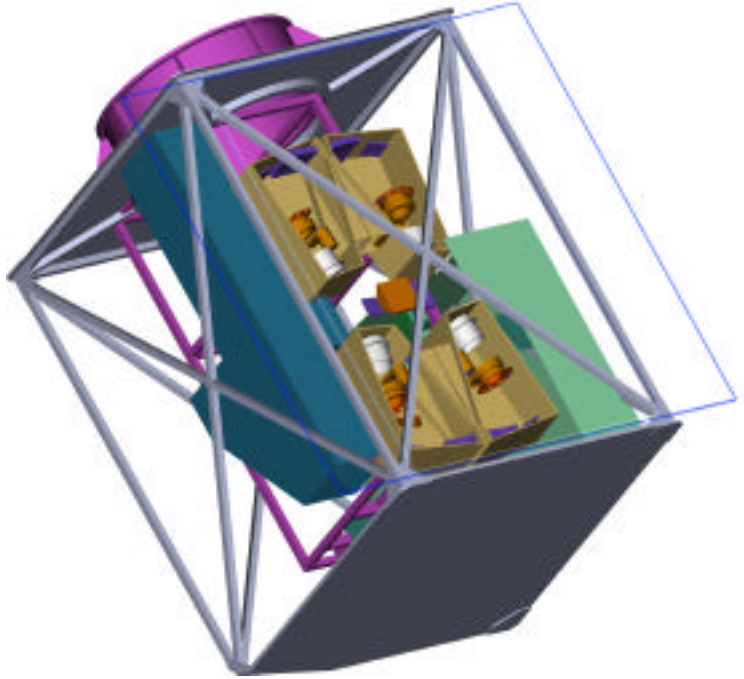
The Physics of Star and Planet Formation – *Making a Home for Life*

- Are planetary systems like our Solar System common? How do they form? Is the chemistry of the Interstellar Medium important in the creation of life?
- To address these complex questions, observations on all scales and many wavelengths must be knit together with theory
- NGST will play an important role with its near- and mid-infrared capabilities by:
  - Determining the physics of star formation: the assembly of stars and proto-planetary disks from cloud cores
  - Imaging and doing atmospheric studies of Jupiter-sized planets at similar (5 AU) distances around nearby stars (50 candidates within 8 pc, needs a simple MIR Lyot stop)
  - Inventorying the pre-biotic materials in star-forming systems

Science Instruments

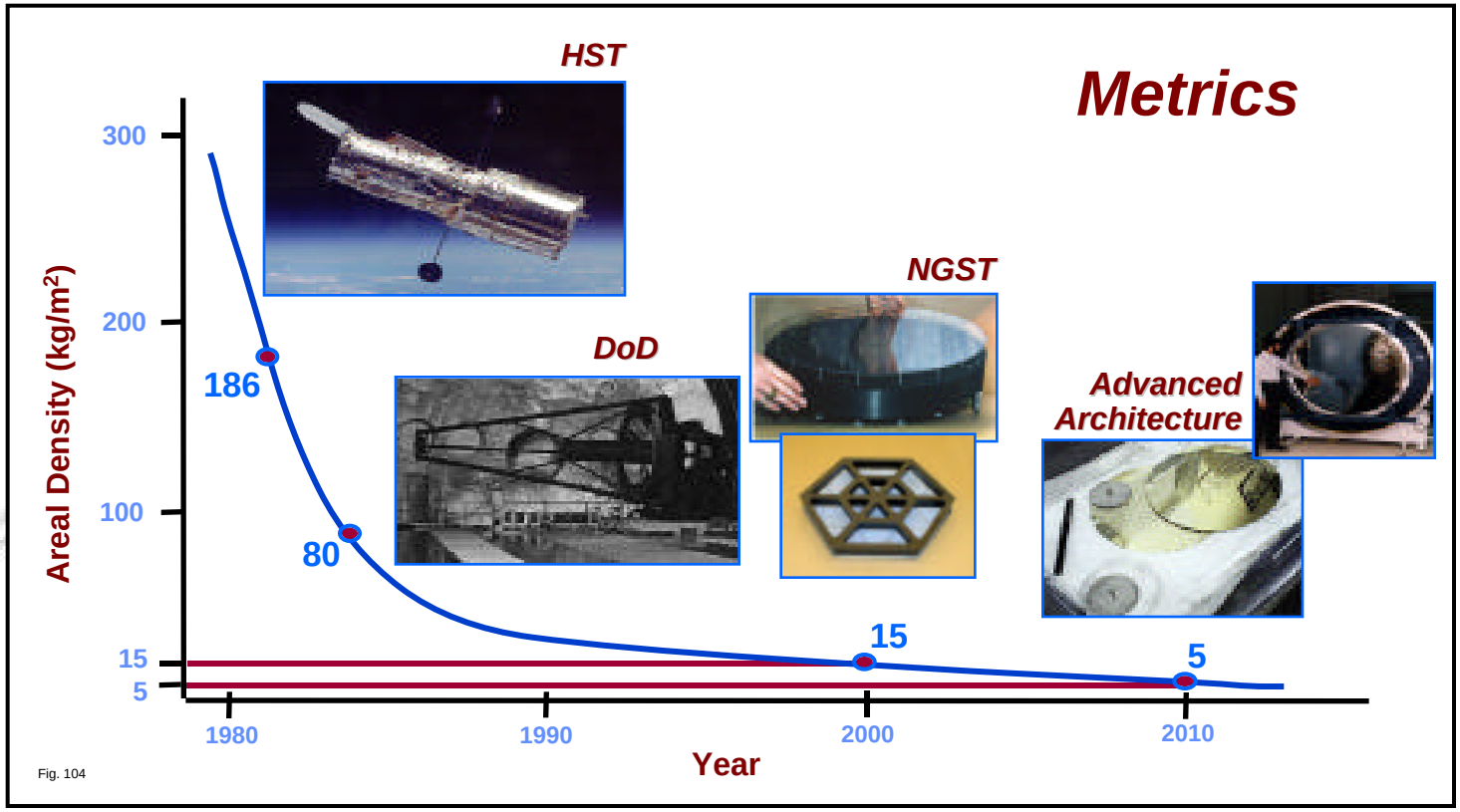
Integrated Science Instrument Module (ISIM) – cold instrument module and data system

- Objective
  - Procure instruments from US/international science community
  - GSFC to integrate PI's flight qualified science instruments, optics, thermal control, electronics into ISIM, deliver to prime as GFE
- Status
  - Concept studies underway in U.S., Canada, Europe
  - International partners agree on instrument selection process
  - NASA HQ schedule concerns addressed, AO release delayed by one year



Technology Challenges

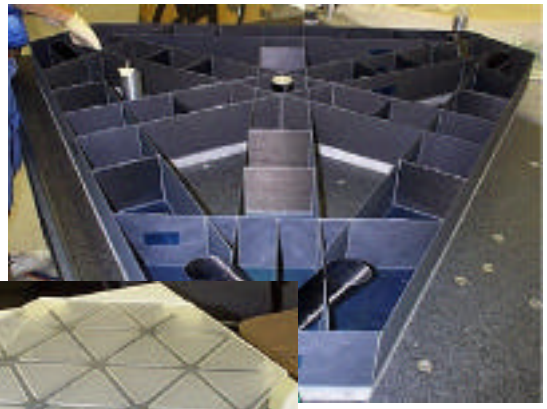
- Top 5 Technologies
  - Optics
  - Wavefront Correction
  - Actuators
  - Detectors
  - Precision Deployable Structures

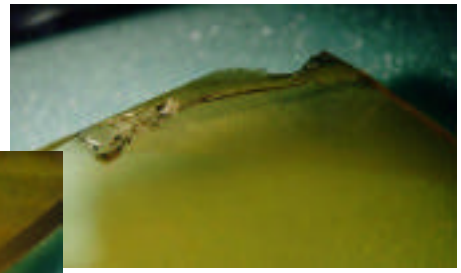


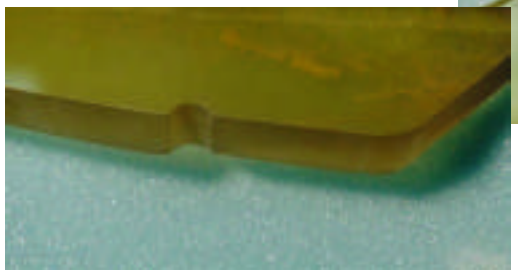
Ultra-Lightweight Active Optics

NGST Mirror System Demonstrator

- Objective
  - <15 kg/m^2 areal density
- Progress
  - UofAA mirror areal density now at 12.4 kg/m^2
  - Solved the COI facesheet fracture problem
  - Selected Phase 1 NASA/AFRL/NRO Advanced Mirror System Demonstrator (AMSD) Contractors
- Problems
  - Bubbles in UofA faceplate
  - COI tool mishap

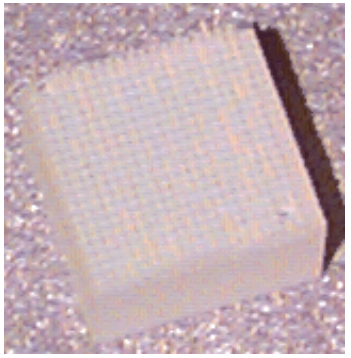


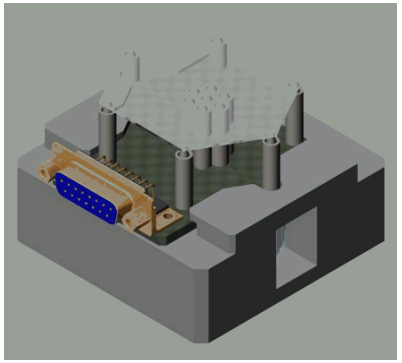




Cryogenic Deformable Mirror

- Wavefront correction device used to compensate for mid-to-high spatial frequency wavefront errors in the telescope
- Objective – integrated NGST, SBIR, Cross-Enterprise technology program plan to develop a flight capable cryogenic DM and lightweight low-power drive electronics.
- Status
  - Executing Phase 3 SBIR with Xinetics – cryogenic measurements on doped $SrTiO_3$ show promising strain levels down to < 10K

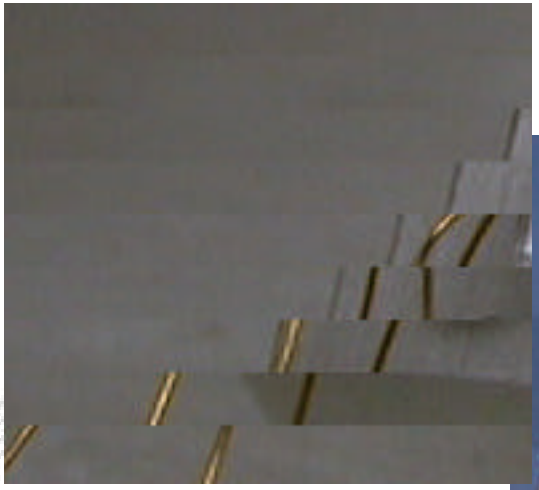




  - American Superconductor DM as a possible second source

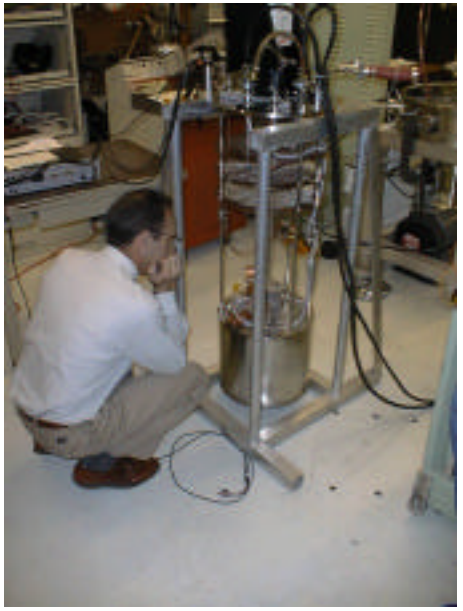
Cryogenic Actuators

- Objective
  - Develop position actuators for mirror alignment and phasing, and force actuators for figure control (35K operation)
  - Status
    - 7 firms building prototype actuators
    - JPL received initial deliveries, performing cryogenic tests



43g U of A Impact-Driven Actuator

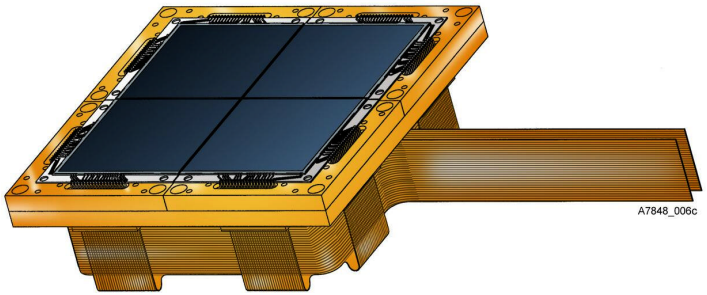
Hatheway & Assoc. Linear Actuator



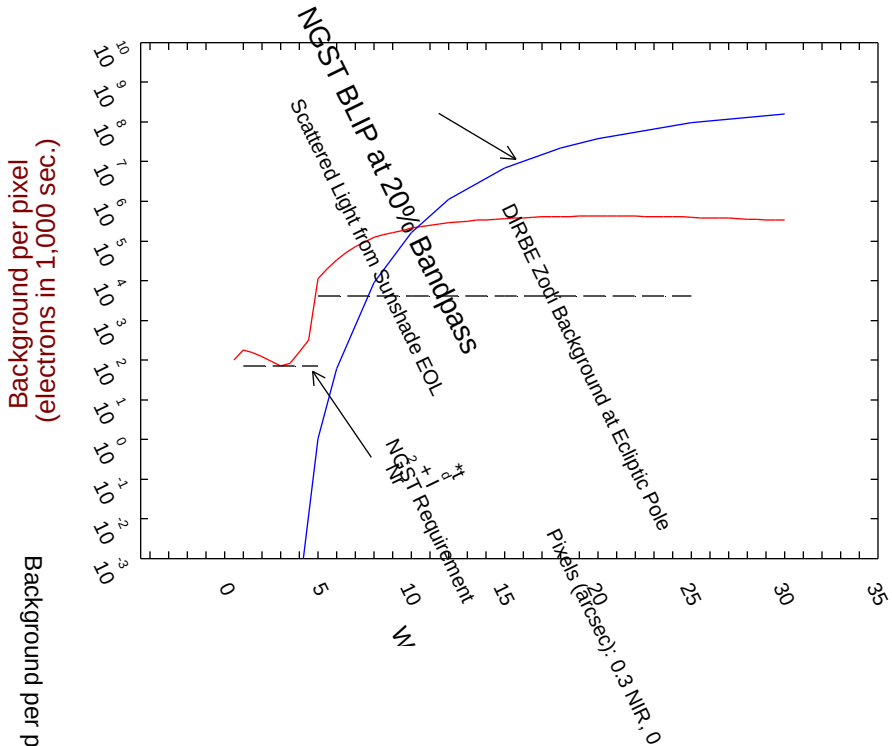
JPL Characterization Test Set

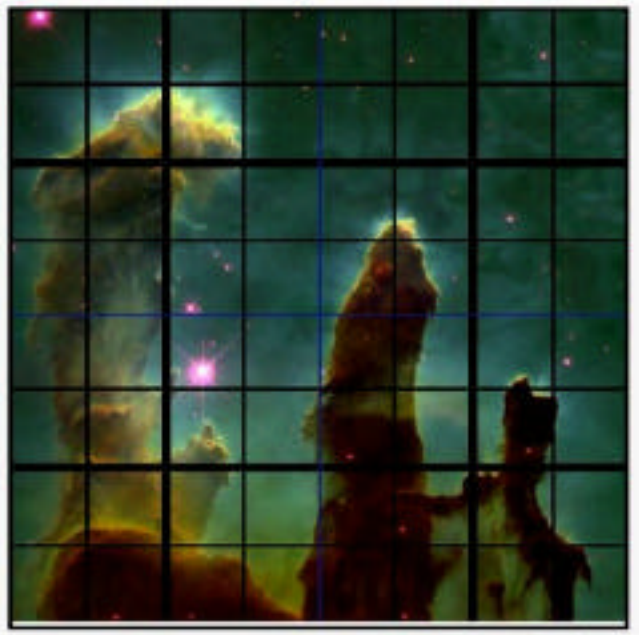
Detector Technology

- Objective – develop Near IR (0.6 - 5 µm, 4k x 4k) and Mid IR (5 - 10+ µm, 1k x 1k) focal planes
  - Yardstick concept utilizes five 16.8 Mpixel FPAs
- Status
  - 6 competitively selected technology contracts underway
  - Large format cryo readouts and packaging
  - Short λ HgCdTe shows good visible performance (> 50% uncoated)
  - Si:As IBCs show 10% reduction in noise relative to SIRTF



Courtesy of Ball Aerospace





Courtesy of J. Hester, P. Scowen (ASU) & J. Morse (U.CO)

Next Generation Space Telescope

NGST

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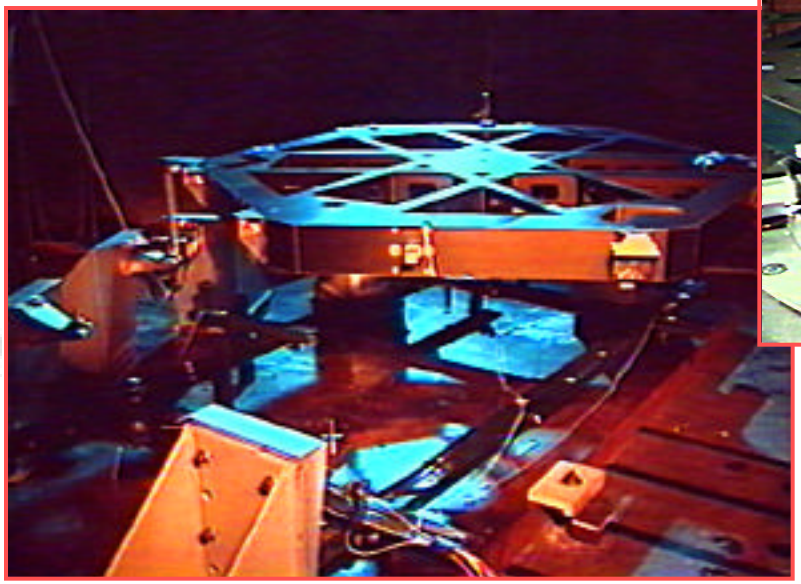
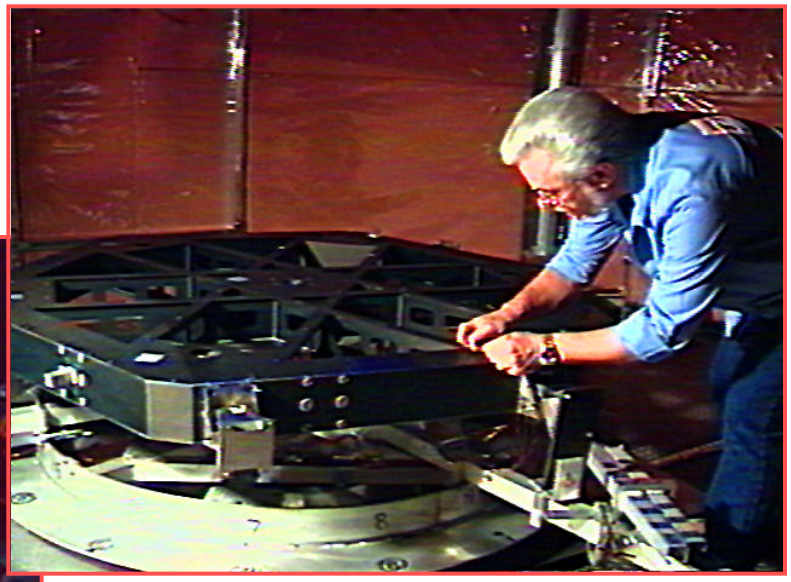
Precision Deployable Structures

- Deployable Optics Testbed Assembly (DOTA)
  - Objective – test precision deployment and latching
  - Status – two segment (one moveable) mirror reaction structure actuated and tested

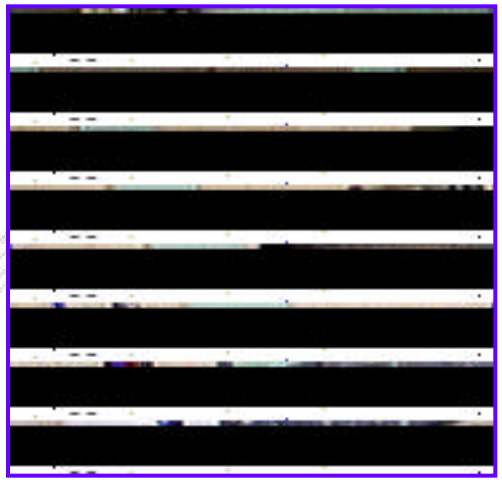


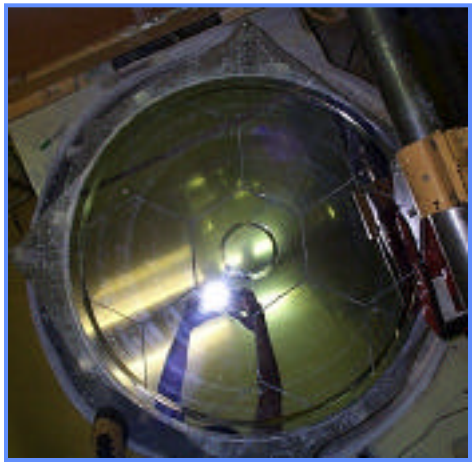


Courtesy of TRW Inc.

Developmental Comparative Active Telescope Testbed (DCATT)

- Objective
  - Investigate optimal strategies for segmented mirror wavefront sensing and control
- Status
  - Completed DCATT stimulus and image-based wavefront sensing and control hardware and software
  - Demonstrated optical control and DCATT “first light” using telescope simulator module
  - Telescope module nearing completion



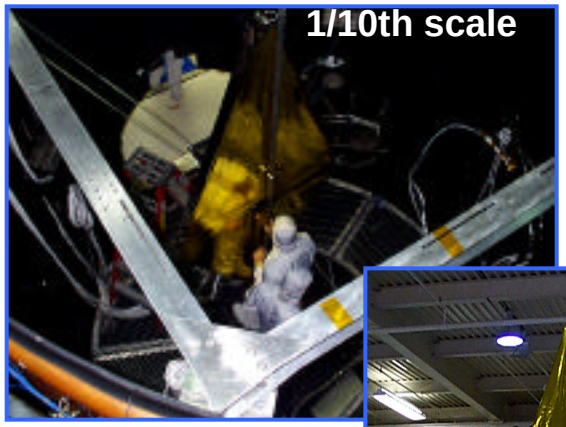


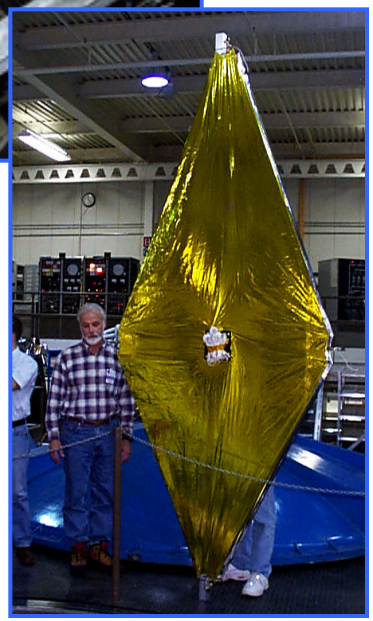
Inflatable Sunshield in Space (ISIS)

ISIS is the shuttle deployment of a 1/2 scale NGST sunshield

- Objective
  - Demonstrate feasibility of inflatable technology for passive cooling, correlate data with predictions
- Status
  - 1/2 scale engineering prototype (4 membrane) shield deployed via inflation on the ground (6/98)

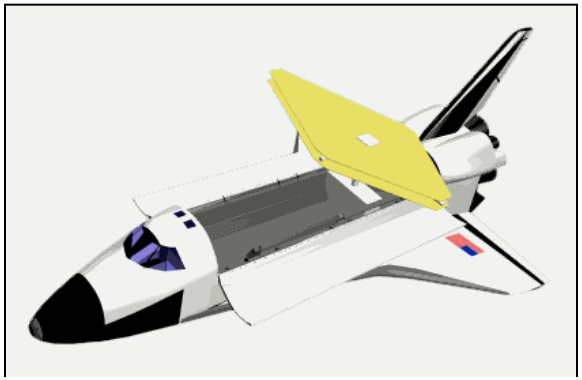
  - Modal testing of 1/10 scale, 2-layer prototype





  - Procuring flight payload and extendible mast

STS-107



Next Generation Space Telescope

NGST

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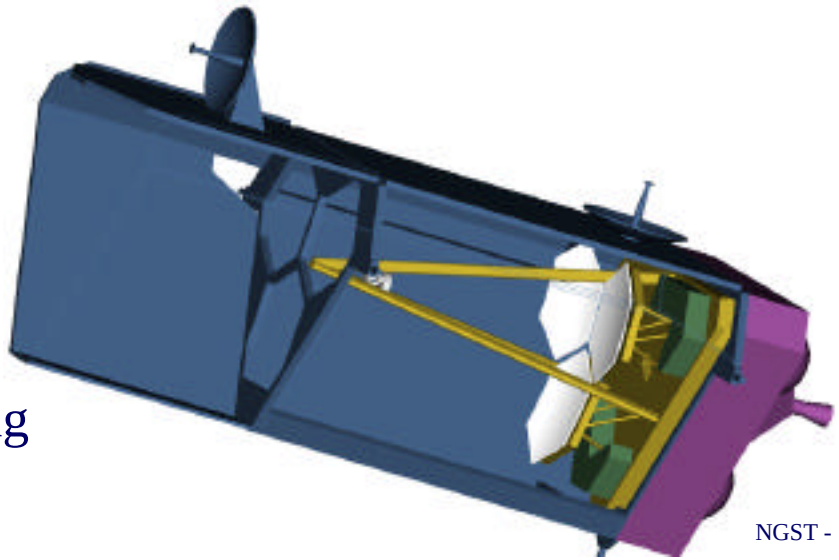
Nexus – Wavefront Sensing and Control Flight Demonstration

Nexus is a 2.6 m segmented infrared telescope – shuttle launched free flyer – that uses AMSD optics and SIRTF-type detectors

- Objectives
  - Demonstrate image-based wavefront sensing and control using a science-grade camera and real stellar sources
  - Quantify performance margins for slew and settle times, zero g release, control-structures interaction, micro/nano dynamics
  - Validate new cost curve for lightweight optics and detectors
- Status
  - Phase A Study in progress
    - PDR in October 1999
    - CDR in December 2000
    - Launch in mid 2003
  - Partnering discussions on-going with DoD and NMP



Next Generation Space Telescope

NGST

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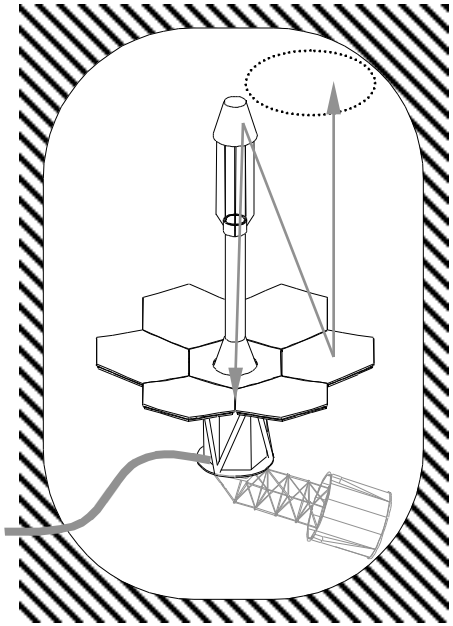
Observatory Verification

System level verification is key to autonomous observatory

- Testing required:
  - Optical image quality (diffraction limited at 2 µm)
  - Dynamic and thermal stability over >24 hours
  - Zodiacal-background limited up to 10 µm
  - Science instruments performance
  - Ground system validation



Next Generation Space Telescope

NGST

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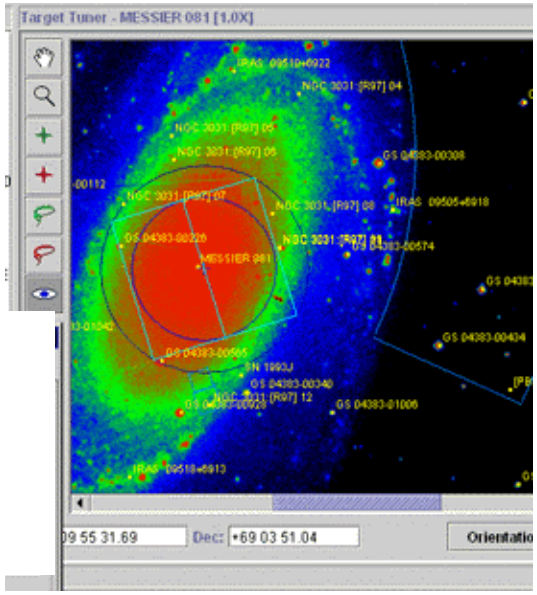
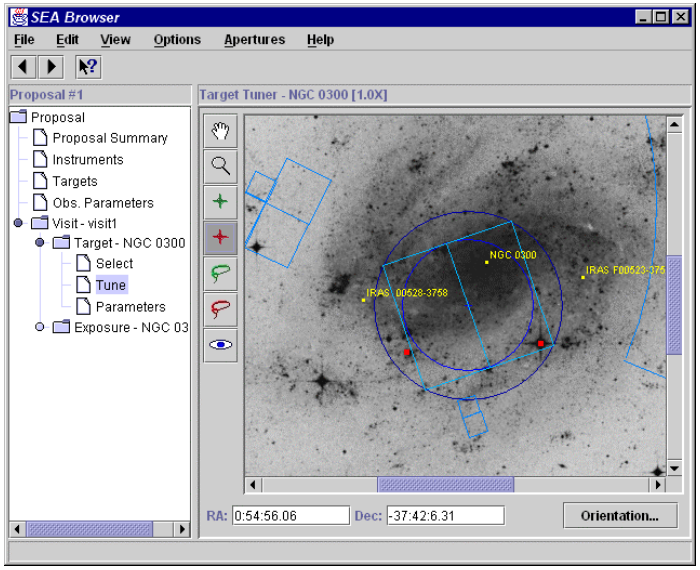
Operations

- Objective
  - Optimize performance for life cycle cost with continuing emphasis on operability
- Status
  - Designated STScI as Science and Operations Center
  - STScI instrument ops study/white paper planned
  - Formal Phase A operations concept study started
  - Initial operating configuration of an expert system for planning observation programs online – ***Scientist's Expert Assistant***
  - Operations working group has generated a list of requirements for an adaptive scheduler

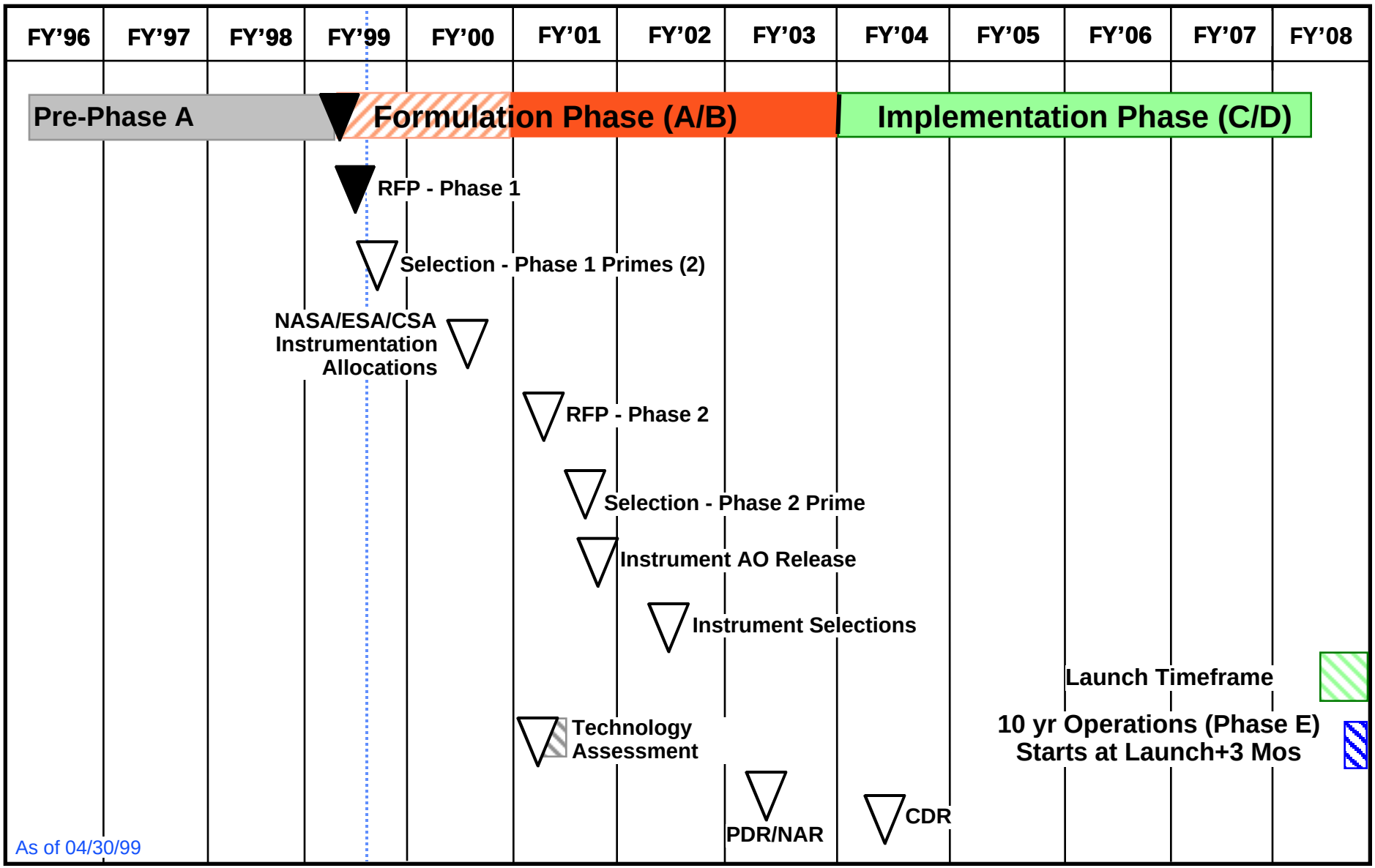




Outreach

- Objective
  - Keep astronomy community informed and involved
  - Develop concensus on science goals and instrument complement
- Activities
  - AAS special sessions (Jan’99, Jun’99…)
  - Decade survey input, website expansion, NGST section of STScI newsletter
  - ASWG now includes CSA, ESA and Japanese representatives
  - Detector workshop at STScI (Apr’99)
  - Woods Hole science-technology meeting (Sep’99)

NGST Top Level Observatory Schedule



International Collaboration


- Motivation for Partnering
  - Increased observatory scientific capability/productivity
  - Increased project contingency
- Resource Portfolio in FY96 US Dollars

NASA	–	$900M	(80%)
ESA	–	$200M	(15%)
CSA	–	$50M	(5%)

- Plans
  - Extend the NASA/ESA MOU for HST while incorporating NGST to maintain the 15% allotment of observing time for ESA astronomers
  - Establish a similar partnering arrangement with CSA for a proportional amount (5%) of NGST observing time
- Documentation
  - Concept Agreement signed by Bonnet/Weiler in December 1998 and Wetter/Weiler in April 1999
  - Letters of Agreement being drafted for both CSA and ESA – May 1999
  - Memorandum of Understanding (MOU) for both under construction

Next Generation Space Telescope
NGST
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Acquisition Strategy

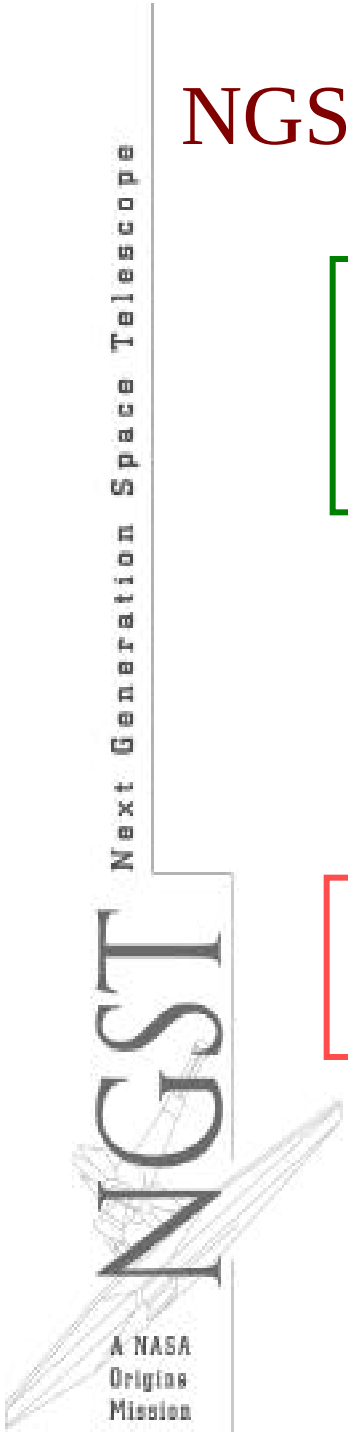
To determine best acquisition approach, NASA analyzed Agency and DoD programs and conducted trades

- **Teaming** *(roles and responsibilities)* – examined a range of options
- **Timing** *(sequence and timing of key events)* – identified independent schedule variables and the interdependence of key events
- **Contracting** *(contract types and regulatory considerations)* – matched risk and responsibility, balanced innovation and precedence

Accomplishments included

- Customized mission acquisition strategy
- Successful ASM for phased procurement on March 24
- Received 4 letters of intent to bid and issued RFP April 23

NGST Risk Management Approach



Strong, Integrated Systems Engineering

Innovative Mission Architecture

New Technologies

Accomplishments FY'98

Scientifically…

- ASWG membership expanded to broaden community participation and support base
- International (ESA/CSA) participation in full swing
  - Joint, integrated schedule
  - Instrument and spacecraft studies
  - Science groups
  - Excellent coordination and collaboration

Technologically…

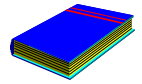
- Significant progress against our technology development roadmap in the mirror, deployable structures, detector, actuator, and expert assistant prototype areas
- Optics community has responded to mirror areal density and cycle time challenges – goal of <15 kg/m^2 within reach
- Embarked on new thrusts in the area of cryogenic effects on materials and structures

Programmatically…

- SRB-recommended systems engineering approach to acquisition strategy really cool
- NASA/ESA/CSA partnering committee has motivated early emphasis on process-schedules-instrument module interface definition
- NGST External Science Review (NESR) has encouraged us to redouble scientific outreach activities

Report Card for Last Year – Accomplishment Metrics

A-



Last Year's Predictions	Status to Date	Comments
• **Technology Development Milestones**		
- 2m Active Optics Segment Prototype (NMSD)	-Schedule slip to Aug-Oct 1999	- REOSC polishing tool mishap and U of A faceplate bubble problem
- DCATT "First Light"	-First light achieved using source simulator module	- Delay in completion of telescope primary due to Oak Ridge failing to meet surface roughness spec
- Cryogenic Actuator Lash-up	-Several cryogenic actuator prototypes demonstrated	- Some have met spec at *both* ambient and cryogenic temperatures
- Technology Readiness Monograph	-Deferred to post-Woods Hole	- ASP to publish the Woods Hole workshop proceedings
- Joint NASA/DoD AMSD RFO	-Complete	- Selections complete; historic partnership in place
• **Architecture Studies**		
- Completion of Pre-A Studies	-Complete	- Documented on the Web
- Competitive Selection of Formulation Partners	-Complete by May 20	- Proposals due May 5; 2-3 month schedule delay due to phased procurement process pathfinding
- Documented Yardstick Analysis	-6 of 12 monographs complete	- In final review cycle
- Cost Break Points as a Function of λ	-Complete	- Results documented on Web and used to generate Phase A/B requirements
- First Correlation of Predicted Optical Control Algorithm with DCATT Testbed Results	-Exercised algorithms for DM correction of segmented optics	- Completion of this task scheduled for Oct 1999

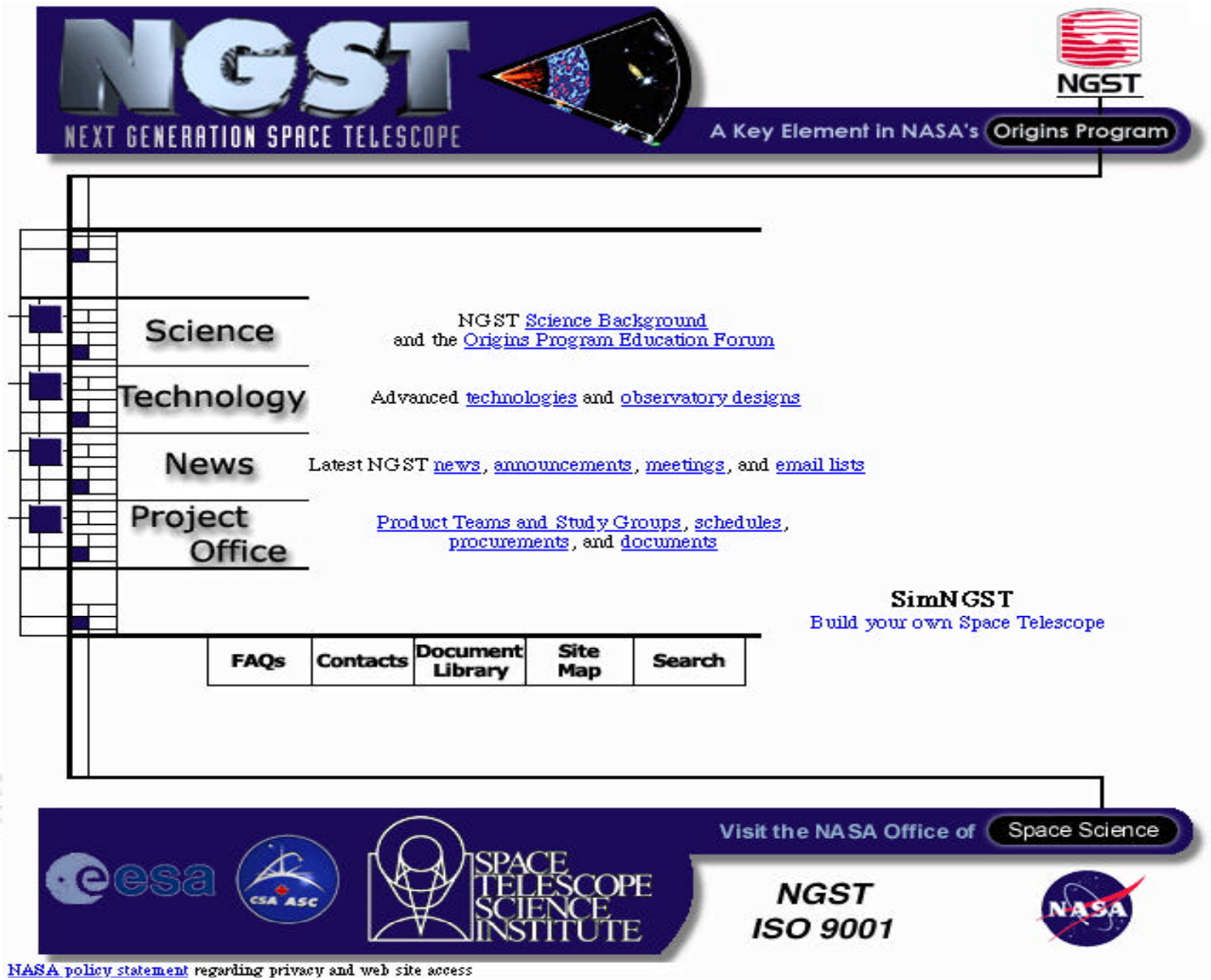
Goals for the Next Year

- Architecture Studies
  - Selection of industry formulation phase partners
  - Allocation process leading to spacecraft and scientific instrument international contributions
  - NGST monograph series
  - Draft observatory verification plan
- Science and Operations
  - STSci operations study
  - Cooperative agreement with STScI for science and operations
  - NRA#2 awards for science instrument technology development
- Technology Development
  - 2-meter class mirror prototypes
  - Woods Hole technology readiness monograph
  - DCATT Phase I experiment milestones
  - Detector multi-chip module prototype development

Three Points to Remember about NGST

- After 2 years of technology development, we have uncovered numerous problems, but none have proved insurmountable
  - *While the ultra-lightweight cryogenic active mirrors look tough but doable, the testing of these low F/# aspheric optics will be one of our biggest challenges in the coming year*
- The international scientific community is engaged, working on over a dozen competitively selected instrument concept and technology studies, and several new ideas are being pursued (e.g., IR MOS and IFTS)
  - *The core science program remains robust*
- Budget shortfalls in FY 02-03 significantly impact the NGST technology program and observatory flight program schedule

http://www.ngst.nasa.gov



Next Generation Space Telescope

NGST

A NASA Origins Mission